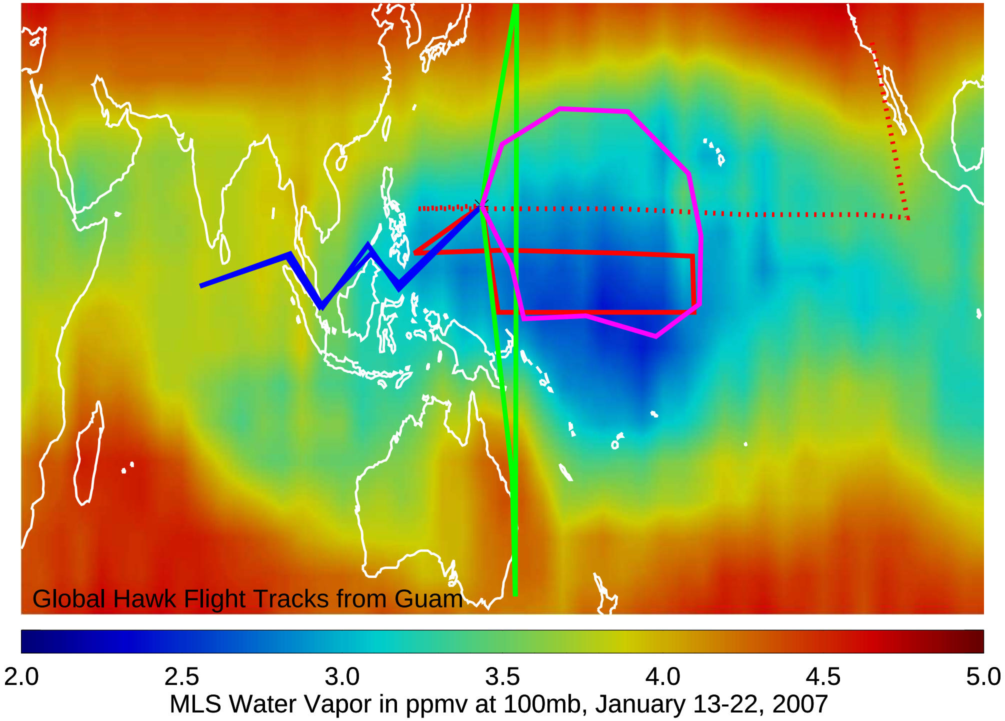
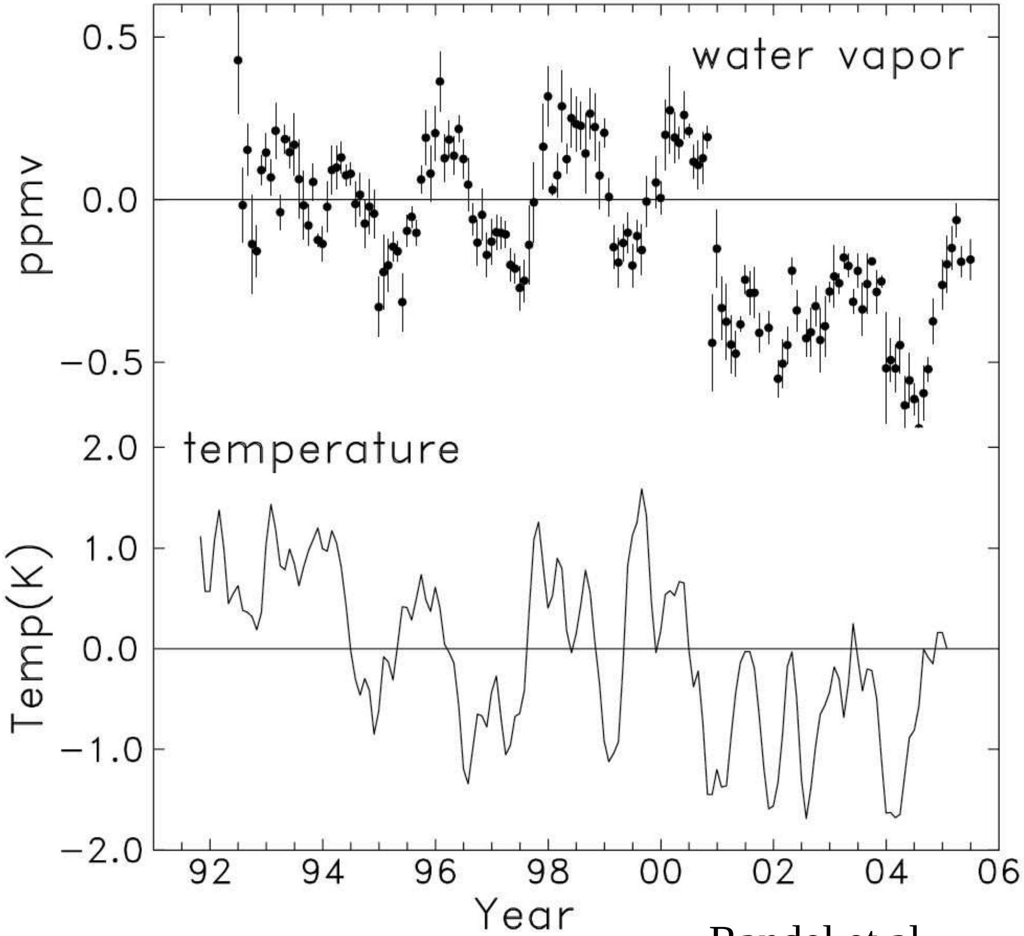
Airborne Tropical TRopopause EXperiment (ATTREX)



- Use NASA Global Hawk to sample clouds, water vapor, tracers, halogens, and radiation in the Tropical Tropopause Layer (TTL)
- Use the ATTREX measurements to improve predictions of climate change and stratospheric ozone

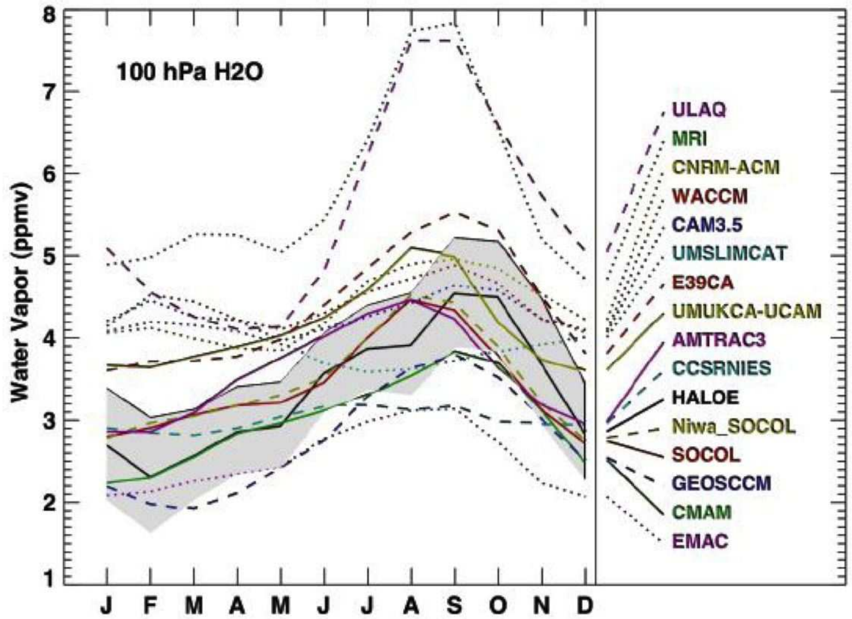


Randel et al.

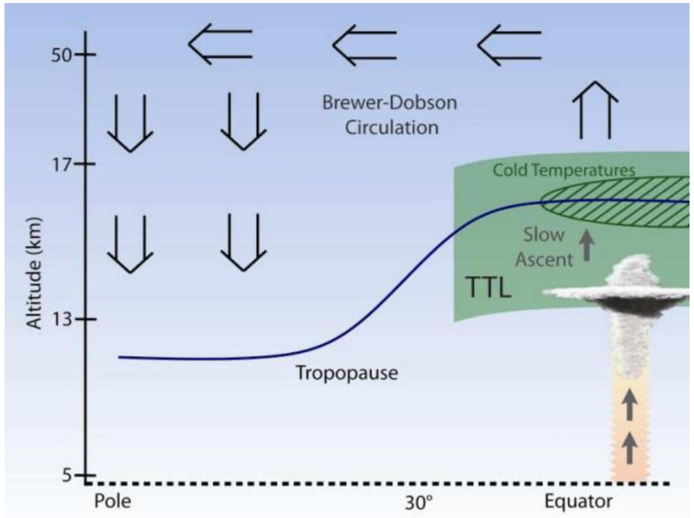
pre 2000 vs post 2000 H2O: −0.1 W/m2

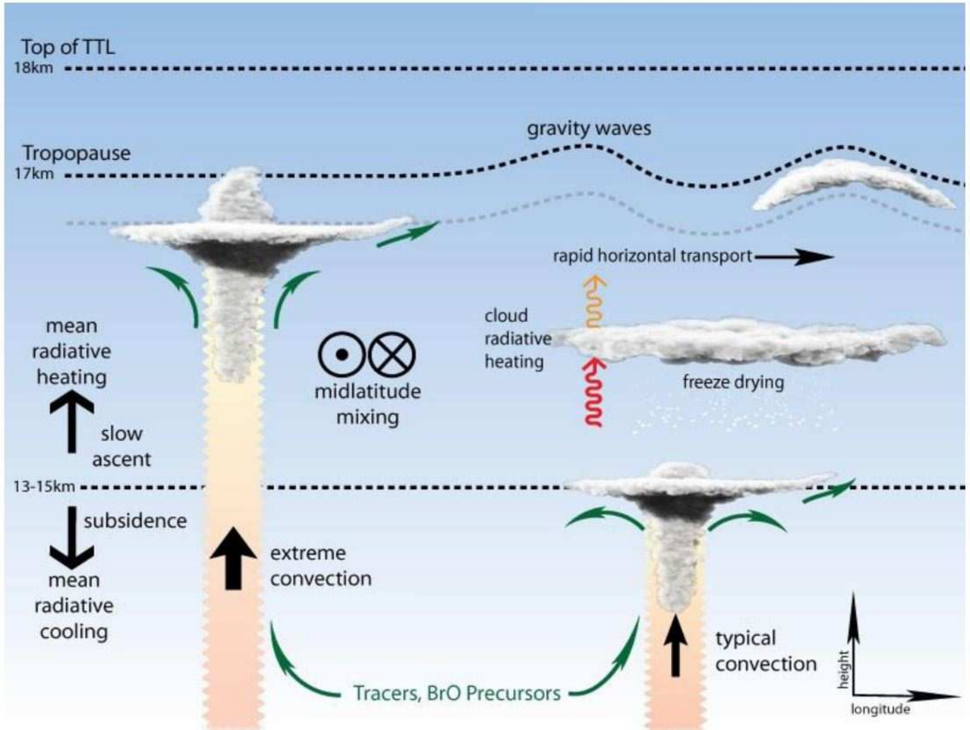
1996−2005 CO2 increase: +0.26 W/m2

[Solomon et al., 2010]



Airborne Tropical TRopopause EXperiment (ATTREX)





Overarching science goals:

1. To improve our understanding of how deep convection, slow large-scale ascent, waves, and cloud microphysics control the humidity and chemical composition of air entering the stratosphere.
2. To improve global-model predictions of feedbacks associated with future changes in TTL cirrus, stratospheric humidity, and stratospheric ozone in a changing climate.

Science questions (abbr.)

1. What are the formation processes of TTL cirrus and how effectively do they dehydrate air entering the stratosphere?
   - Lagrangian flights through TTL cirrus sampling T, H_2O, and cloud microphysics

2. What roles do tropical waves play in the maintenance of and variability in tropical upwelling within the stratospheric transport circulation?
   - Use long Global Hawk flight legs to sample waves with scales between $\simeq$300 km (measured with conventional aircraft) and $\geq$ 6000 km (resolved by satellites)

3. What is the relative importance of typical convection detraining at 13 km versus extreme convection detraining above 15 km for the humidity and composition of air entering the stratosphere?
   - Sampling of tracers with different lifetimes to improve model representation of TTL transport and convective influence

4. What is the effect of TTL cirrus on the Earth's radiation budget and TTL radiative heating?
   - Direct measurements of TTL cirrus radiative heating and microphysical properties

Science questions (cont.)

1. How might the TTL thermal structure be altered in a changing climate, and what are the potential feedback effects?
   - Use ATTREX measurements to improve GCM representations of processes affecting TTL temperature (tropical waves, radiative budget, convection, etc.)

2. What is the vertical distribution of BrO and short lived halogen compounds in the TTL and how does it vary seasonally and geographically?
   - First direct measurements of TTL BrO; comparison with satellites and models

NASA Global Hawk

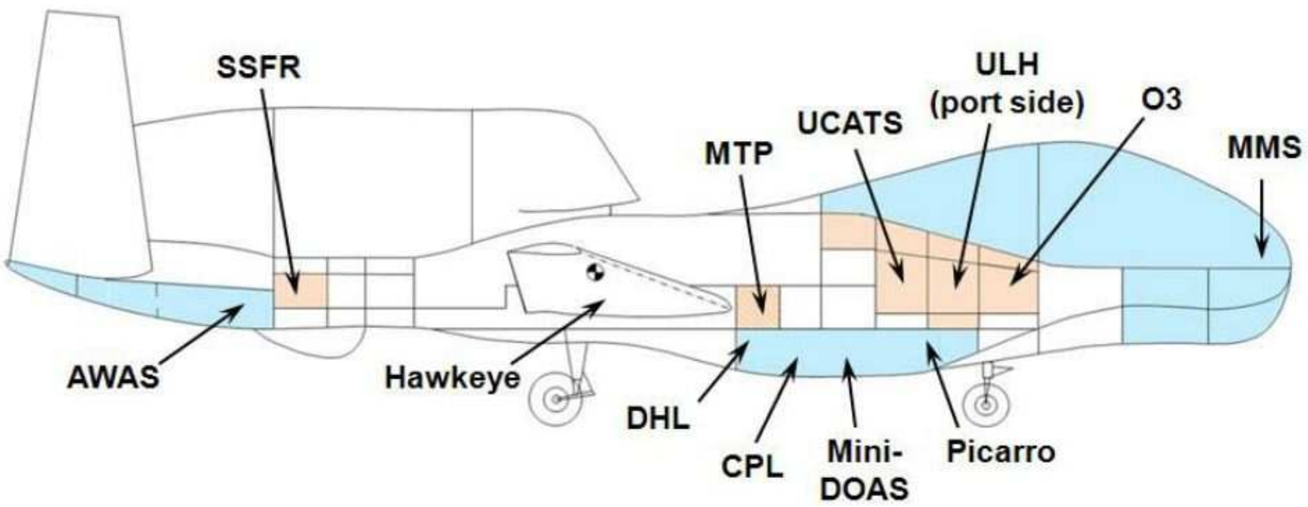
15−20 km altitude

30−hour (11,000 nmi) duration

~1,000 lbs payload

ATTREX Global Hawk Payload

Instrument	Investigator	Measurements
Cloud Physics Lidar (CPL)	M. McGill	aerosol/cloud backscatter
Advanced Whole Air Sampler (AWAS)	E. Atlas	many tracers w/varying lifetimes
UAS Chromatograph for Tracers (UCATS)	J. Elkins	O_3, CH_4, N_2O, SF_6, H_2O, CO
NOAA Ozone	R. Gao	O_3
Picarro Cavity Ringdown Spectrometer	S. Wofsy	CO_2, CO, CH_4
UAS Laser Hygrometer (ULH)	R. Herman	H_2O
Diode Laser Hygrometer (DLH)	G. Diskin	H_2O
Hawkeye	P. Lawson	Ice crystal size dist., habits
Solar, Infrared Radiometers	P. Pilewskie	Radiative fluxes
Meteorological Measurement System (MMS)	P. Bui	Temperature, pressure, winds
Microwave Temperature Profiler (MTP)	M. Mahoney	temperature profile
Absorption Spectrometer (DOAS)	Stutz/Pfeilsticker	BrO, NO_2, OClO, IO



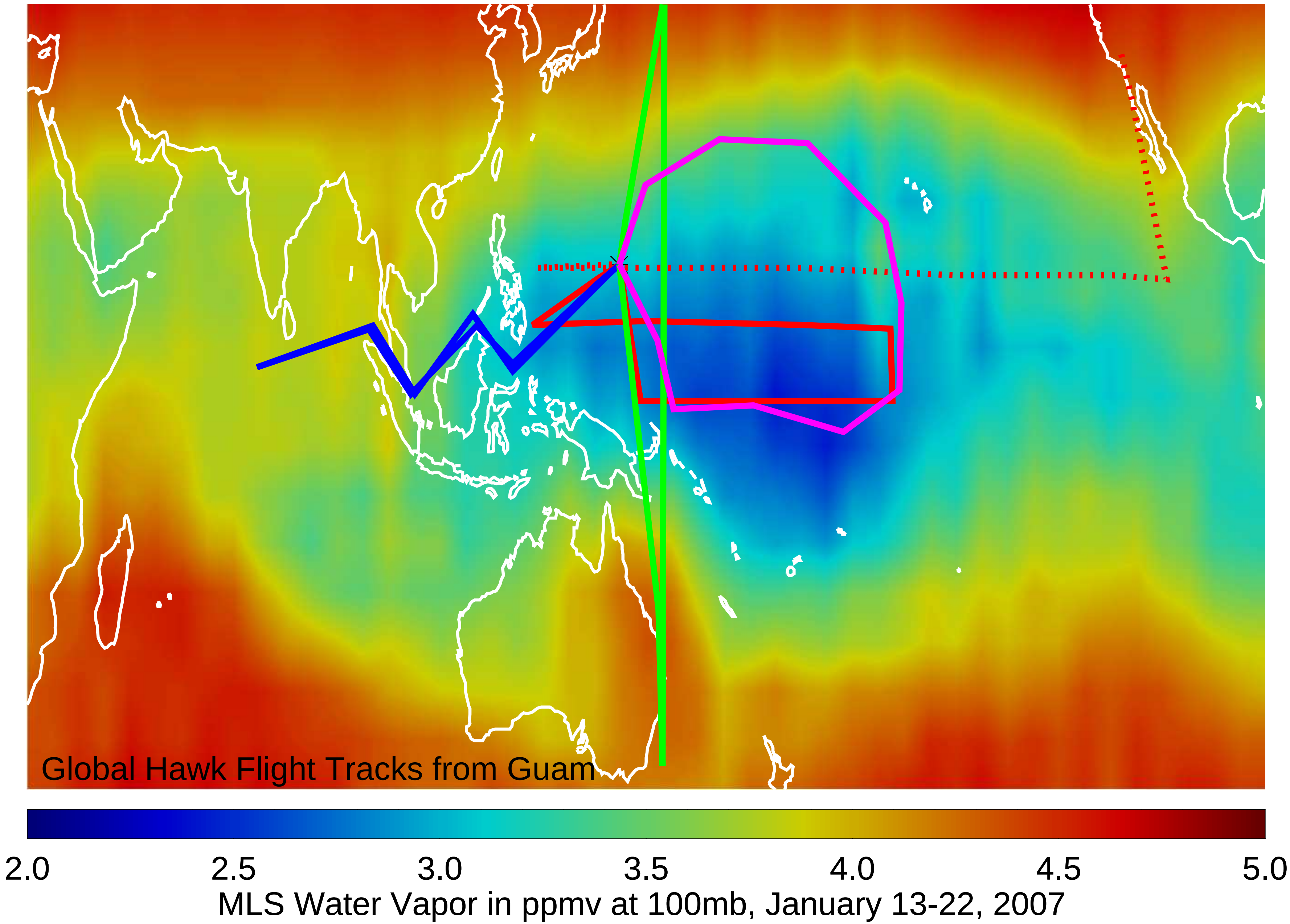
Deployment Sites

Dryden: late summer 2011

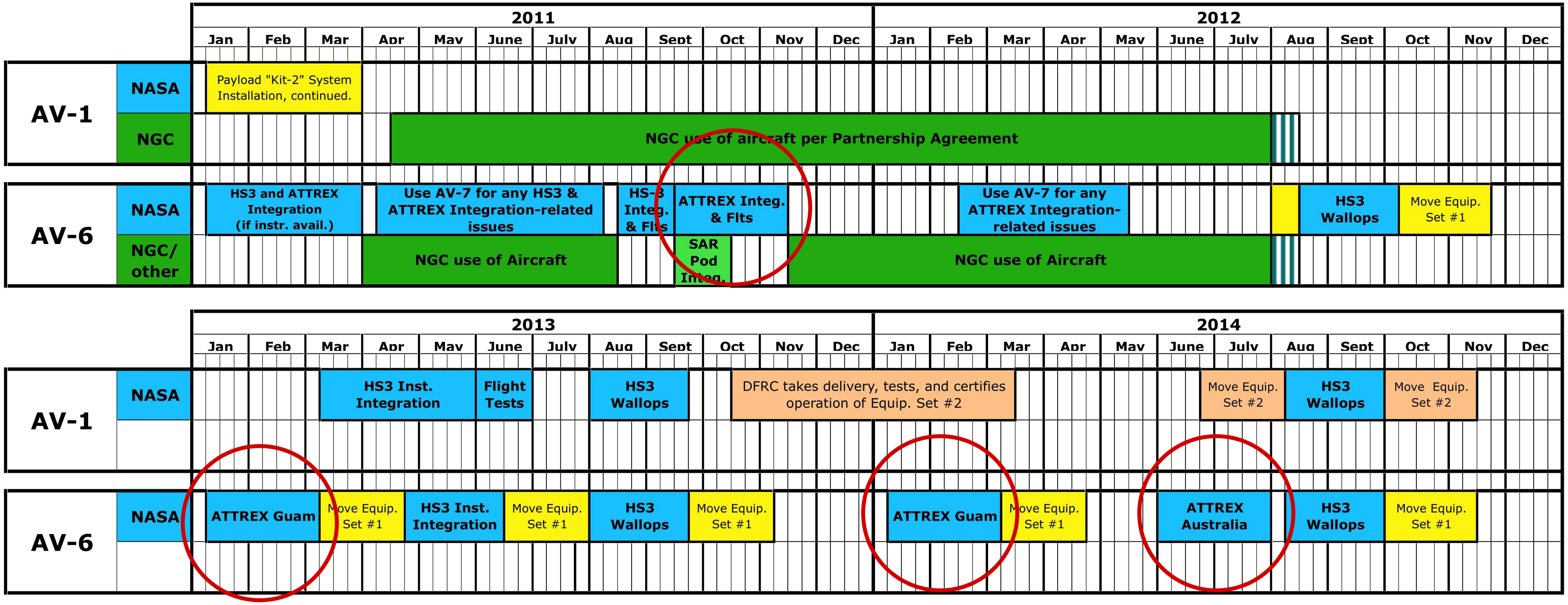
Guam: Jan−Feb 2013

Guam: Jan−Feb 2014

Darwin: Jun−Jul 2014


Global Hawk Flight Tracks from Guam
2.0
2.5
3.0
3.5
4.0
4.5
5.0
MLS Water Vapor in ppmv at 100mb, January 13-22, 2007

ATTREX Schedule



Partnerships: NSF GV

- Global Hawk limited to flying above $\simeq$13–14 km and far away from convection

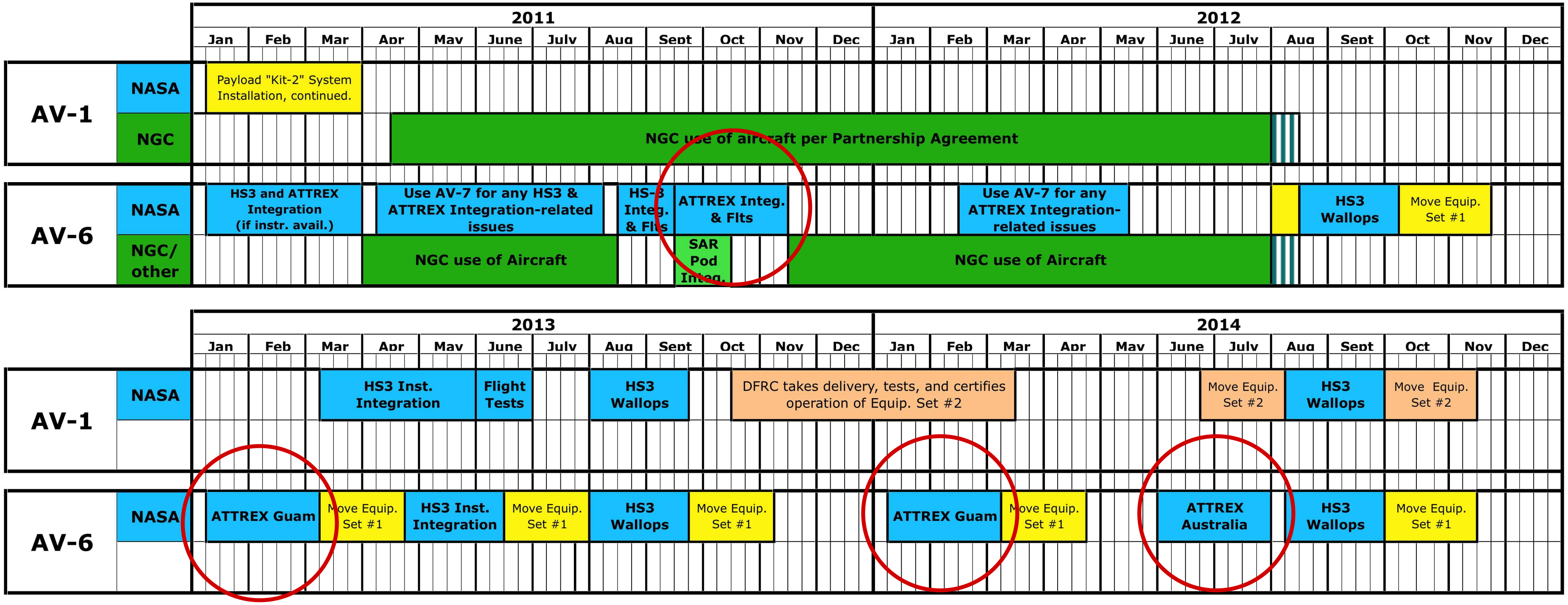
- GV can sample lower TTL ($\simeq$12–14 km) at and above the main convective detrainment altitude

- Similar tracer package as Global Hawk + additional chemistry, aerosol measurements, cloud microphysics, etc.

Frostpoint balloon soundings

- Coordinated with GH takeoffs and/or landings
- Comparison with GH water vapor measurements
- Possibilities:
  - NOAA CFH soundings
  - SOWER collaboration
  - Frostpoint launches at DOE TWP sites (Nauru, Darwin)
  - German GRUAN project [H. Vömel]

ATTREX Schedule

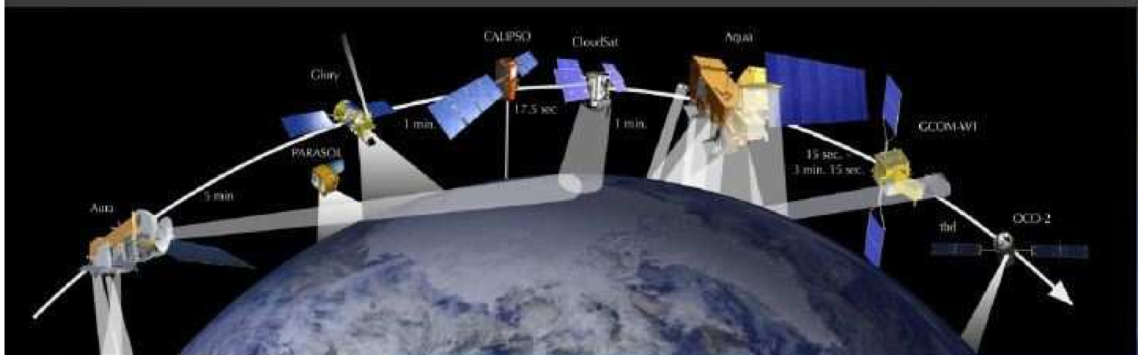


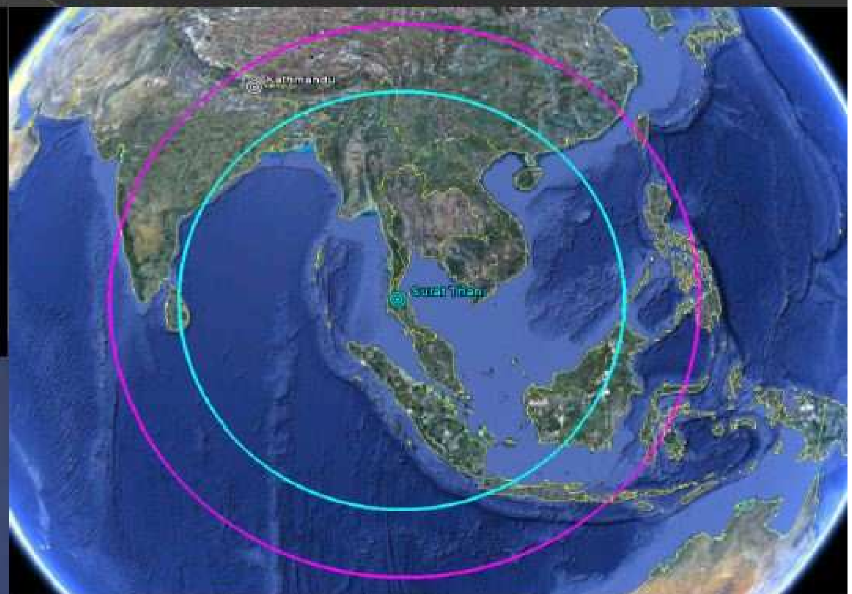
Southeast Asia Composition, Cloud, Climate Coupling Regional Study (SEAC^{4}RS)

A NASA airborne field campaign focusing on atmospheric composition, chemistry, and climate over **Southeast Asia** related to:

- Asian monsoon circulation impacts on upper troposphere/lower stratosphere composition
- Biomass burning impacts on atmospheric composition, radiation, and clouds

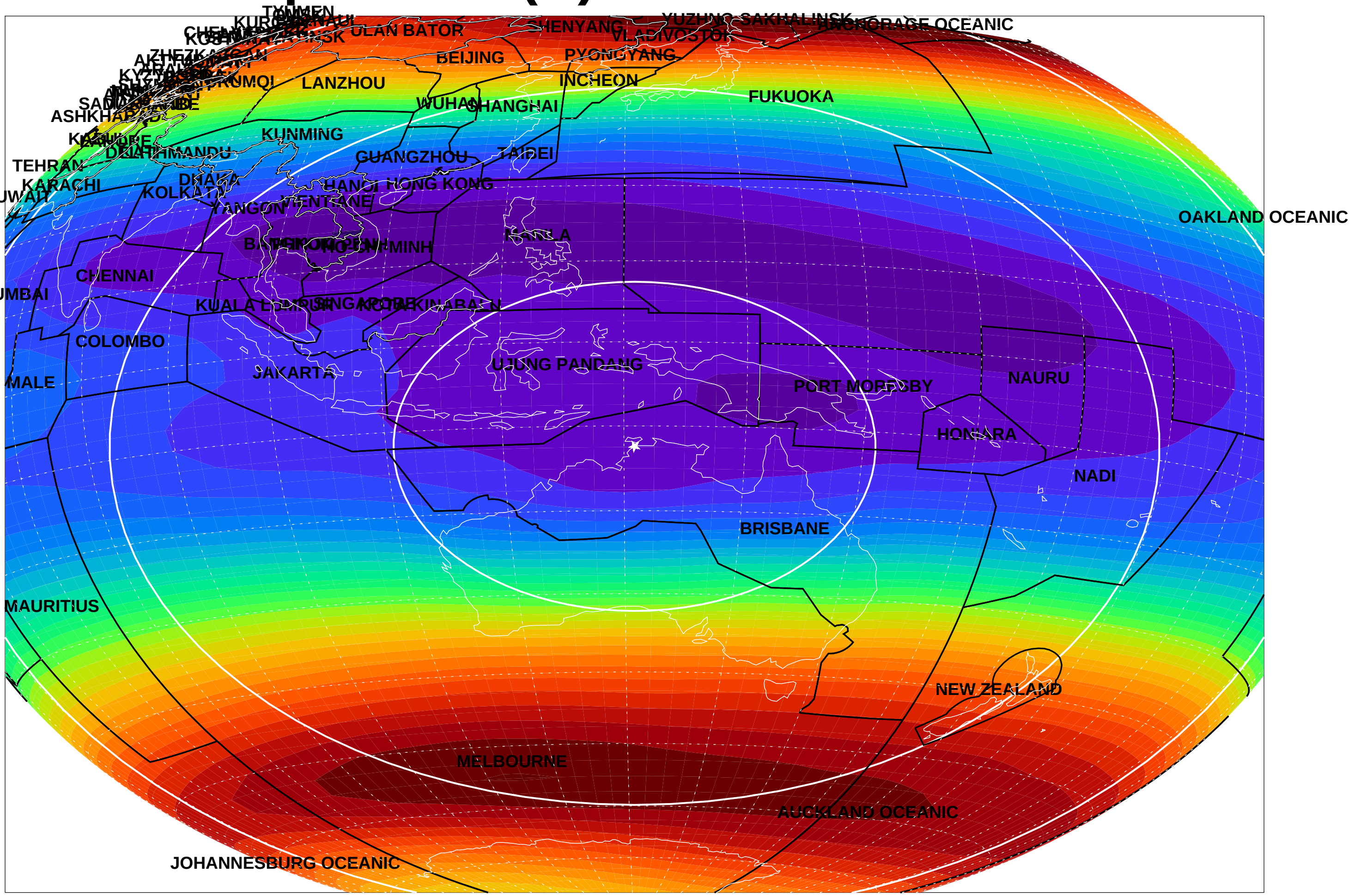
Anticipated deployment period: **August - September 2012**





Challenges: 1. Flight clearances

Temperature (K) 1979-2009 100 hPa



Challenges: 2. Remote Global Hawk deployments

- First time basing Global Hawk operations outside the U.S.
- Global Hawk Mobile Operations Facility (under development), Payload Mobile Operations Facility

Challenges: 3. Global Hawk operations constraints

- The Global Hawk is a fair weather airplane (similar to ER-2, but no pilot)
- GLOPAC constraints: no wet runway, no clouds on takeoff/landing, no flying over convection
- Easing of restrictions is expected over time